Overview of NASA's Environmentally Responsible Aviation (ERA) Project

A NASA Aeronautics Project focused on midterm environmental goals

N+2 Advanced Vehicle Concepts & Quick-Starts NRA Pre-Proposal Meeting
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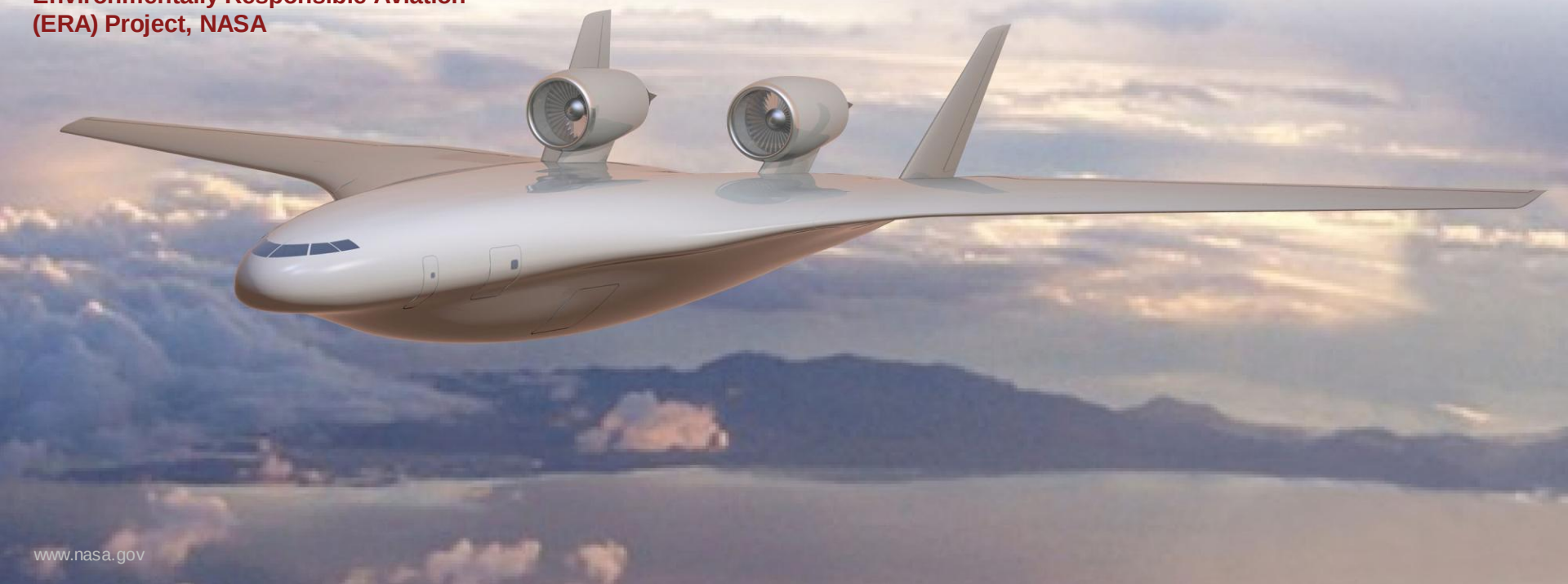


National Plan for Aeronautics R&D Context for the ERA Project

- Mobility, Security/Defense, Safety, Energy & Environment
  - Enable growth in Mobility/Aviation/Transportation
  - Dual use with Security/Defense
  - Safety and Cost Effectiveness are pervasive factors
- Specific and Quantifiable Energy and Environment goals
  - Energy Diversity
    - use of alternative fuels, not creation of alternative fuels
  - Energy Efficiency
  - Environmental Impact
    - reduction of impacts, not reducing scientific uncertainties of impacts

NASA System Level Metrics

…. technology for dramatically improving noise, emissions, & performance

CORNERS OF THE TRADE SPACE	N+1 = 2015*** Technology Benefits Relative To a Single Aisle Reference Configuration	N+2 = 2020*** Technology Benefits Relative To a Large Twin Aisle Reference Configuration	N+3 = 2025*** Technology Benefits
Noise (cum below Stage 4)	-32 dB	-42 dB	-71 dB
LTO NO_x Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-50%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

***Technology Readiness Level for key technologies = 4-6

** RECENTLY UPDATED. Additional gains may be possible through operational improvements

* Concepts that enable optimal use of runways at multiple airports within the metropolitan area

ERA Approach

- *Focused on N+2 Timeframe – Fuel Burn, Noise, and NO_x System-level Metrics*
- *Focused on Advanced Multi-Discipline Based Concepts and Technologies*
- *Focused on Highly Integrated Engine/Airframe Configurations for Dramatic Improvements*

ERA Project Framework

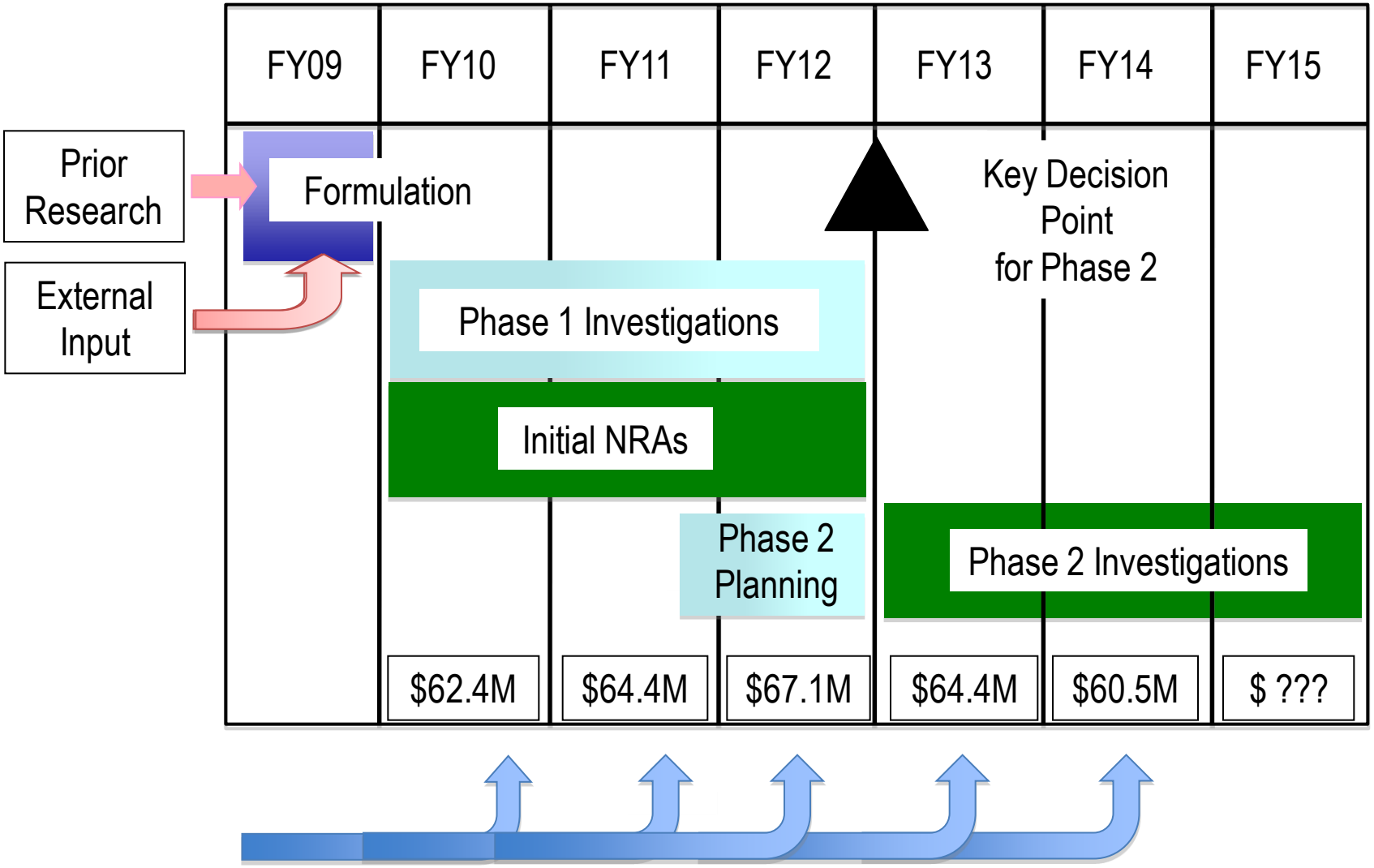
- Vision
  - ERA will expand the viable and well-informed trade space for vehicle design decisions enabling simultaneous realization of National noise, emissions, and performance goals
  - ERA will enable continued aviation growth while reducing or eliminating adverse effects on the environment
- Mission
  - Perform research to explore/assess the feasibility, benefits, interdependencies, and risks of vehicle concepts and enabling technologies identified as having potential to mitigate the impact of aviation on the environment
  - Transfer knowledge outward to the aeronautics community, and inward to NASA fundamental aeronautics projects
- Scope
  - N+2 vehicle concepts and enabling technologies
  - System/subsystem research in relevant environments

The Way Forward

- System research to bridge the gap between fundamental research (TRL 1-4) and product prototyping (TRL 7)
  - Identify vehicle concepts with the potential to simultaneously meet National goals for noise, emissions, and fuel burn in the N+2 timeframe
  - Understand the concept and technology feasibility/risk vs potential benefits
  - Understand the concept and technology trades and interdependencies at high fidelity in relevant environments
  - Determine safety implications of new technologies and configurations

- Technology investments guided by
  - matured in fundamental program and worthy of more in-depth evaluation at system level in relevant environment
  - systems analysis indicates most potential for contributing to simultaneous attainment of N+2 goals
  - identified through stakeholder input as having potential for contributing to simultaneous attainment of N+2 goals

ERA Project Flow
And Key Decision Point for Phase 2

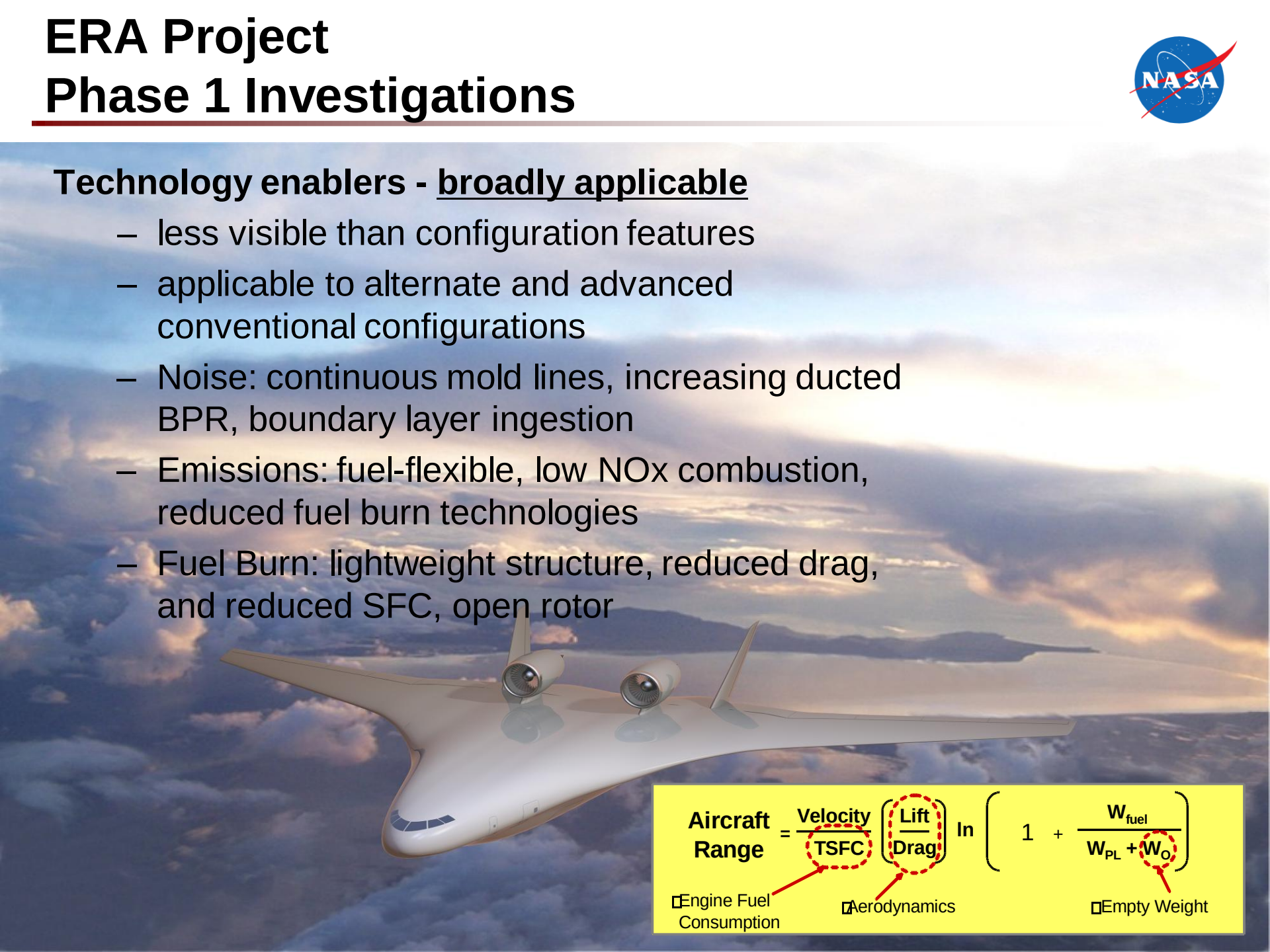


Technical input from Fundamental Programs, NRAs, Industry, Academia, Other Gov't Agencies

ERA Project
Phase 1 Investigations

Technology enablers - broadly applicable

- less visible than configuration features
- applicable to alternate and advanced conventional configurations
- Noise: continuous mold lines, increasing ducted BPR, boundary layer ingestion
- Emissions: fuel-flexible, low NOx combustion, reduced fuel burn technologies
- Fuel Burn: lightweight structure, reduced drag, and reduced SFC, open rotor



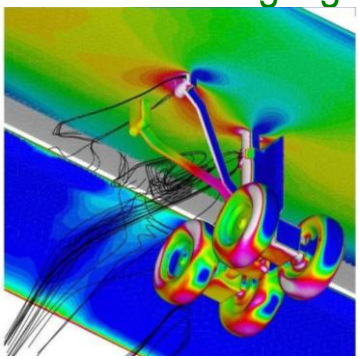
$$\text{Aircraft Range} = \frac{\text{Velocity}}{\text{TSFC}} \left(\frac{\text{Lift}}{\text{Drag}}\right) \ln\left(1 + \frac{W_{fuel}}{W_{PL} + W_O}\right)$$

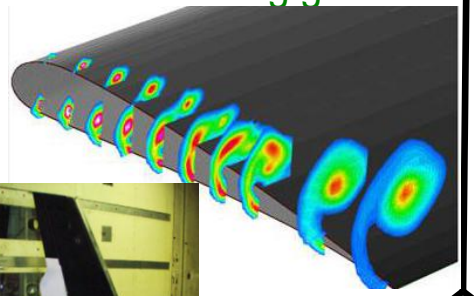
- Engine Fuel Consumption
- Aerodynamics
- Empty Weight

Addressing Noise Reduction

Airframe Noise

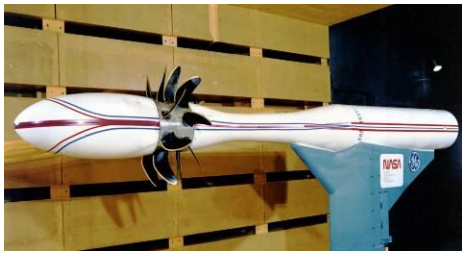
Addressing high-lift systems and landing gear





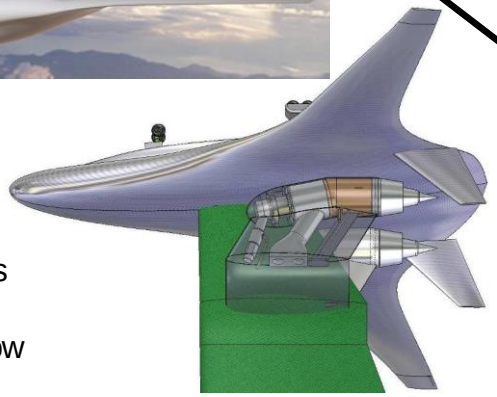
Propulsion Noise

Addressing fan, core, and jet noise



Open Rotor

UHB Turbofans



- Twin High Bypass Ratio Jet Simulators
- Simplified Fan Noise Simulator
- Instrumentation and Processing for Low Noise Levels

Propulsion Airframe Aeroacoustics

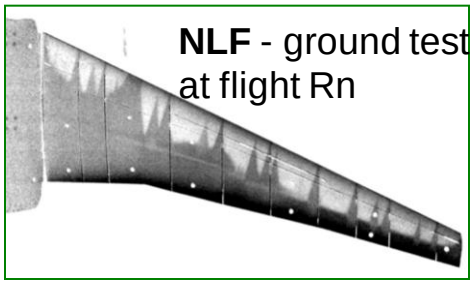
Addressing airframe/propulsion interaction - shielding

Addressing Fuel Burn (CO_2 Emissions)

DRAG REDUCTION via Laminar Flow

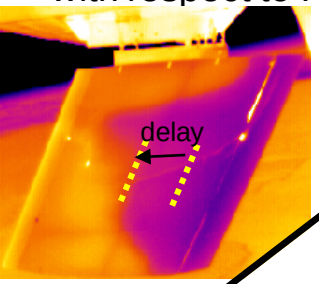
Addressing concepts & barriers
to achieving practical laminar flow on transport a/c

HLFC - revisit crossflow expt
- understand system weight



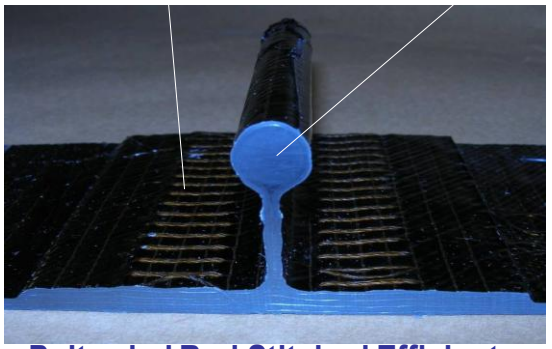
NLF - ground test at flight Rn

DRE - exploring the limits with respect to Rn

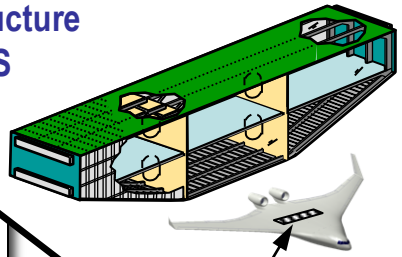


WEIGHT REDUCTION via Advanced Structures

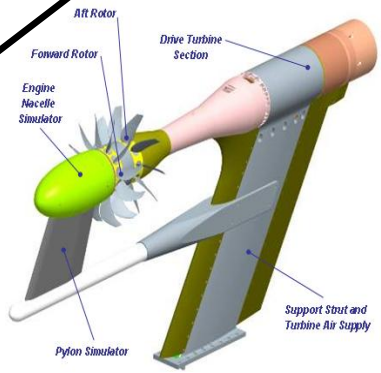
Moving from "safe-life" to "fail-safe" design
with a lightweight composite structure



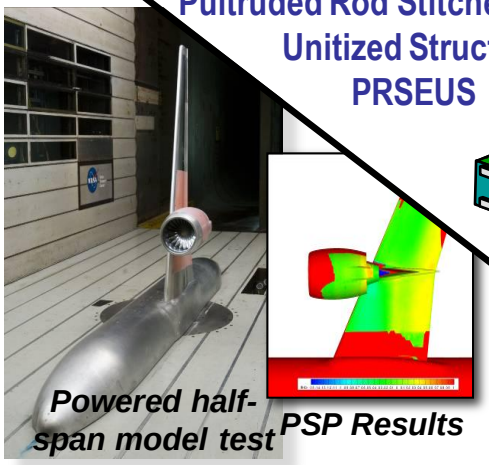
Pultruded Rod Stitched Efficient Unitized Structure PRSEUS



Test Region



Open Rotor Propulsion Rig



Powered half-span model test

PSP Results

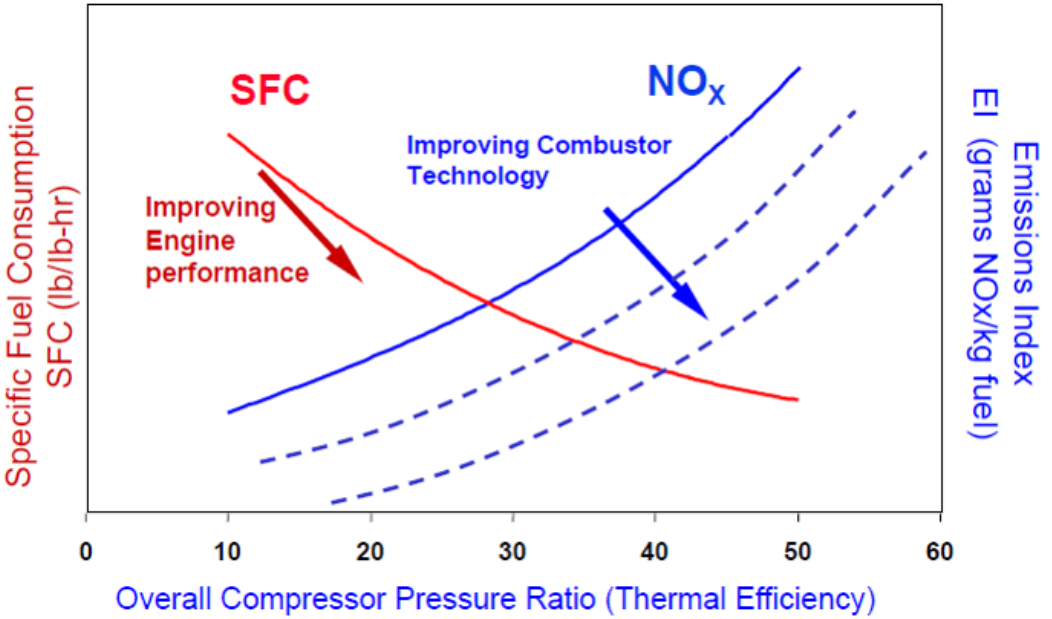
SFC REDUCTION via UHB

Addressing multidisciplinary challenges from subcomponent to installation
to achieve ultra-high by-pass ratio

Addressing Reduced LTO NO_x Emissions

Low NOx combustor concepts for high OPR environment

Increase thermal efficiency without increasing NOx emissions



NASA Injector Concepts

- Partial Pre-Mixed
- Lean Direct Multi-Injection

Enabling Technology

- lightweight CMC liners
- advanced instability controls

- Improved fuel-air mixing to minimize hot spots that create additional NOx
- Lightweight liners to handle higher temperatures associated with higher OPR
- Fuel flexibility to accommodate emerging alternative fuels
- Coordinating with DoD Programs

ERA Project - Initial NRAs
Broad-based input to the ERA Project

- Topic 1 - N+2 Advanced Vehicle Concepts – Pre-Proposal Meeting Feb. 19
  - **Concept development and technology roadmaps**
  - **Scope key system Investigations to inform Phase 2 decisions**

- Topic 2 - Low NOx Combustors – Selections made (January 2010)
  - **Concept development and technology roadmaps**
  - **Initial flametube experiments**
  - **Inform Phase 2 decisions**

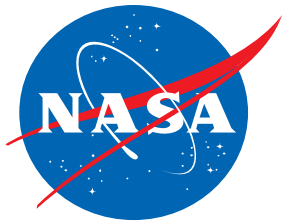
- Topic 3 - Quick-Start System Research Investigations – Pre-Proposal Meeting, Feb. 19:
  - Quickstart NRA 1: PAI and PAA Study
  - Quickstart NRA 2: Wing Design with Flight Weight HLFC Systems
    - **Complementary to Phase 1 investigations**
    - **Early technical progress/results toward ERA goals**
    - **Inform Phase 2 decisions**

Topic 2: ERA Combustor NRA: N+2 Advanced Low Nox Combustor Technologies

- Goals:
  - Expand the viable and well-informed trade space for vehicle design decisions
  - Enable simultaneous realization of national noise, emissions, and performance goals.
- NRA Scope:
  - Identify new combustor concepts capable of meeting N+2 NOx goals by:
    - Conducting initial screening experiments,
    - Developing enabling technologies,
    - Generating additional technology development roadmaps, and
    - Providing a multi-injector sector for evaluation at NASA at realistic engine conditions.
- Selections:
  - GE-Aviation and Pratt & Whitney have been selected and are in negotiations for the NRA contract.
  - Award is pending.
  - An announcement will be made at the time of award.

Topic 2: ERA Combustor NRA: N+2 Advanced Low Nox Combustor Technologies

- **Desired outcome of combustor design & testing:**
  - Meet LTO NOx goal of 75% reduction from CAEP 6 in screening tests
  - Meet LTO NOx goal of 75% reduction from CAEP 6 in multi-injector sector tests at realistic N+2 engine conditions
  - Exhibit cruise NOx reduction compared to state-of-the-art capability for an engine with 50,000 to 60,000 lbs thrust
  - Result in no increase of carbon monoxide, unburned hydrocarbons or smoke, and particulates relative to CAEP 6 levels
  - Exhibit fuel flexibility with alternative fuel
  - Demonstrate acceptable combustion stability over the complete operating range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